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Climate of the Past Discussions

Interactive comment on "Extending and understanding the South West Western Australian rainfall record using a snowfall reconstruction from Law Dome, East Antarctica" *by* Yaowen Zheng et al.

Anonymous Referee #1

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The authors propose a reconstruction of precipitation in South West Western Australia (SWWA) based on snowfall estimate from an ice core in East Antarctica. The authors also compare this reconstruction with model results to identify the role of various forcings and natural variability in the rainfall changes during the past 2000 years. This allows them to conclude that the recent decrease in precipitation is likely due to anthropogenic forcing. The topic of the study is very interesting. The proposed statistical analyses are well described and justified. Precipitation reconstructions are rare in the region so a long time series as the one proposed in the manuscript is more

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than welcome and the analyses are useful to understand the potential origin of the reconstructed changes. However, I see several issues that need to be addressed, to reach stronger and more robust conclusions, before the paper can be accepted for publication.

General points

1. A previous study (van Ommen and Morgan, 2010) has proposed a link between precipitation in SWWA and snowfall at Law Dome. The authors confirm this link based on a least square linear regression. They discuss the validity of this statistical link but not the mechanisms that could explain it. A few lines are available in the introduction, based on the results of van Ommen and Morgan, (2010) but we have now 10 more years of data and it would be instructive to see if this confirms the conclusions reached 10 years ago or not. A point that seems puzzling is the link between an annual mean record (Law Dome) and precipitation during the growing season in SWWA. This should be discussed and justified.

2. For the reconstruction, the authors assume the stationarity of the link between snow accumulation at Law Dome and precipitation in SWWA, as classically done. However, that stationarity needs to be tested. A classical test is to separate the time series in a calibration period, over which the statistical model is developed, and a validation period, over which its skill is evaluated. In this framework, it is important to test how the magnitude of the correlation is influenced by the post 1971 trend, calibrating for instance the model over the period 1900-1971 and evaluating then the correlation over 1971-2015. This is important for the reconstruction as, if the link is weaker before 1971 (because of a strong role of the anthropogenic forcing on the observed link), this could decrease the validity of reconstruction for the pre-industrial period. In this framework, this would be nice on Figure 2 to have also the observed time series of precipitation in SWWA and snow accumulation at Law Dome for a first visual comparison of the records.

3. For the stationarity, this should also be tested using the model results to check if the model reproduce well the observed correlation for the 20th century and if the value remains stable for the previous centuries.

4. The authors compare the pre-industrial period (before 1850) with the recent past but the justification of this date is based on a commonly admitted value, not on the reconstruction itself. From a visual interpretation of the curve, it seems to me that not shift is present at that time in the series. This could be tested with the methods used to detect the shift in 1971. The differences between 22BCE-1849 and 1851-2015, shown for instance on figure 4, may be only due to the period 1971-2015. This could be tested by checking if there is also a difference between the periods 22BCE-1849 and 1851-1971. If there were no difference, this would mean that changes really occurs after 1971, not after 1851 (as discussed for Figure 6). This would also have an impact for the interpretation and for the model-data comparison as the the shift in 1850 seems clearer in the model (this should be tested too).

5. There is a good justification to use results from the CSIRO Mk3L climate model for the past millennium as not many ensemble exists with different forcing. Nevertheless, a strong point in the discussion is the post 1971 shift. The model underestimate this shift. The authors rightly argue that this may be because the model does include stratospheric ozone forcing (lines 335-336). This can be easily tested using climate model results available for this period, but including ozone forcing. A main conclusion of the study is that anthropogenic greenhouse gases have contributed to the observed decline in precipitation but this is based on one model, which do not include one of the potentially dominant forcing to explain the changes. Comparing the reconstruction with other models results, in particular those including stratospheric ozone forcing, would allow reaching stronger and more valid conclusions. It would also allow discussing the potential reasons why the shift occurs in 1971 and not earlier.

6. The way internal variability is addressed in not always adequate. The reconstruction should always be compared to an individual member (or the range of the members)

not to ensemble means. Ensemble means are useful to identify the forced response. However, ensemble means should not be used for the control run (lines 304), as for Figure 7 (if I understand well the figure). The interest of the control run is to estimate the range of internal variability as simulated by the model and this is strongly reduced for ensemble means by construction. If you use the ensemble mean, you cannot reach any conclusion on the role of internal variability in the sentence 'Examining each of the ensembles in turn, we see that CONTROL does not capture the key features of the the rainfall' (lines 307-308, two time 'the' before 'rainfall'.).

7. The comparison between the recent drying and past dry periods is too short (see for instance lines 289-291) to reach strong conclusions (lines 369-371) This is an interesting point and the way this comparison is performed should be explained and justified much more extensively.

Specific points

1. Line 19. Just by curiosity, the growing season in the region is winter (May to October)? Is it the growing season also for wheat that is mentioned line 23?

2. Line 97. What is the method used to obtain a reconstruction at a resolution of 0.05°? This should be mentioned as this could explain part of the spatial structure obtained in Figure 1 for instance.

3. Line 136. This is probably not very important for your results but a running average is not a very good method for smoothing and other filters, simple to implement but with much better properties, are available.

4. Line 208. I do not understand why the comparison is between ensemble means and the reconstruction and which estimation of uncertainty is expected (see main point 6).

5. Line 212 'lalso' instead of 'also

6. Line 222. I do not follow 'has shown the feasibility of investigating'. Please reformulate.

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7. Line 238-239. This role of recharging events seems very speculative as it is presented. Is there references to support this hypothesis?

8. The way the variable is presented on Figure 3C seems a bit strange to me. If CUSUM gives the cumulative sum of the record, what is the interest of 'the 45-year running change in the rainfall reconstruction CUSUM series' compared to a running mean on the series itself? There are maybe differences (in the magnitude in particular) but, if this diagnostics does not bring strong new information, it is probably simpler to just show the smoothed reconstruction.

9. Lines 244-245. I did not understood what is the exact difference between 'the step changes' and 'changes of the gradient' in the present framework.

10. Lines 251 'subsampled from the 501 CE to 2000 CE series'. Do you mean that you only take a part of the series?

11. Caption of Figure 5. What is 'the reconstruction in period 1850–2000 CE from the 501–2000 CE series', here too a part of the series?

12. Table 5. What means 'Sample represents to each rainfall simulations'?

13. For me, all the appendices could be moved to a supplementary material.

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